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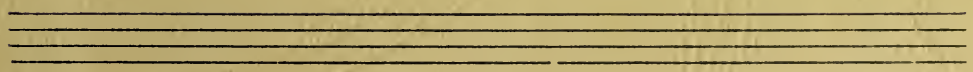


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FOSSIL HISTORY OF *LIMARIA ORIENTALIS* IN NEW ZEALAND

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ABSTRACT

Specimens of *Limaria orientalis* (A. Adams & Reeve) are known from one Oligocene, six Miocene, five Pliocene, and more than 20 Pleistocene localities in New Zealand. Specimens are found mainly in shallow-water shellbeds, and in the extensive Wanganui coastal sequence they are recorded from only eight shellbeds and are not known from at least 25 intervening formations. Probably the discontinuous fossil record was caused by the infrequent preservation of near-shore environments during most of Tertiary time, and by a combination of this and frequent extinctions and reinvasions during Pleistocene time.

INTRODUCTION

One of the most striking events in the recent influx of Pacific molluscs into the New Zealand area was the sudden invasion and rapid spread of *Limaria orientalis* (A. Adams & Reeve) during the summer of 1972. Before 1972 the species had never been recorded in the Recent fauna of New Zealand, and yet it is now one of the common intertidal molluscs of eastern North Island from the Bay of Islands to Coromandel Peninsula. The recent invasion has been discussed by Anon. (1972), Willan (1973), Grange (1974) and Powell (1974). Hypotheses about the manner of arrival of *Limaria orientalis* have been numerous, and mechanisms range from Japanese fishing boats to floating marine objects. Powell (1974, p.203) suggested that the recent invasion is one of several that have occurred during Tertiary and Quaternary time, as a specimen from Target Gully, Oamaru (Lower Miocene) and the Castlecliffian *Promantellum marwicki* (Powell) (Powell 1926, p.48, pl.6, fig. 3, 4) appear to belong in *Limaria orientalis*. Clearly the extent of the New Zealand fossil record of *L. orientalis* has a bearing on the interpretation of the manner of recent migration to New Zealand, so the writer has examined all fossil specimens of *Limaria* in collections of the New Zealand Geological Survey and the National Museum to try and evaluate its fossil record.

THE FOSSIL RECORD

A list follows of the localities at which specimens have been collected that are considered to belong in *Limaria orientalis*. Of these, one is Oligocene, six are Miocene, five are Pliocene, and more than 20 are Pleistocene, and undoubtedly many more Pleistocene localities will be discovered. The distribution of records of *L. orientalis* in the sequence of New Zealand Cenozoic stages is shown in Fig. 12. Almost all specimens of *Limaria* known from New Zealand are judged to be referable to *L. orientalis*, the exceptions being small, finely sculptured specimens from several mid to late Eocene localities (*L. inconspicua*

(Marwick, 1926) and related forms, possibly referable to *Limea*) and two incomplete Duntroonian (Oligocene) specimens from Castle Hill Basin, Canterbury, of the same size and shape as *L. orientalis* but with markedly finer and more closely spaced radial ribs.

It is presumably significant that almost all records are from richly fossiliferous, near-shore shellbeds, and some are from conglomeratic shellbeds that were deposited in very shallow water. The distribution in the Wanganui coastal sequence (Upper Waipipi Shellbed, Wilkies Shellbed, Kupe Formation, Lower Castlecliff Shellbed, Pinnacle Sand, Tainui Shellbed, Upper Castlecliff Shellbed, and Landguard Sand; Fleming 1953) is enlightening, as the species is apparently absent from at least 25 intervening formations recognised by Fleming (1953) and seems to be restricted to a very narrow range of especially richly fossiliferous, near-shore, sandy shellbeds that were deposited where there was little estuarine influence. This presumably means the fossils occupied the same shallow, mainly intertidal, sheltered environments, nestling in coralline algal turf and between oysters on open shores, and under boulders on mud flats in the outermost parts of large estuaries, as *Limaria orientalis* inhabits most commonly now in eastern Northland.

Fossil localities:

Duntroonian (Oligocene): GS241, green tuff, Whitewater Creek, Castle Hill Basin, Canterbury (Boreham in Gage 1970, p.543), a single valve the same shape and size as Recent shells, ribbing very narrow but widely spaced, comparable with the most finely sculptured Recent shells. [Similar large specimens in GS239 and GS3350, from the same locality as GS241, appear to belong in a different species, having very much more numerous, fine, closely spaced ribs.]

Otaian or Altonian (lower Miocene): specimens of "*Mantellum* sp." indistinguishable from small specimens "from Awamoan beds at Ardgowan and Target Gully" were reported by Laws (1939, p.472; 1944, p.298) from Pakaurangi Point, Kaipara Harbour, Northland. As Powell (1974, p.203) identified a specimen from the "Awamoan" (now included in Altonian) Target Gully Shellbed as *L. orientalis*, the Pakaurangi Point specimens probably belong here also, but no Pakaurangi Point shells were available for examination in this study.

Altonian (Lower Miocene): Target Gully Shellbed, Oamaru, Finlay Colln. (Powell 1974, p.203); GS9500, excavation for septic tank alongside Oamaru-Awamoan road, near Old Rifle Butts, South Oamaru, P. A. Maxwell Colln., one perfect small valve, ribbing comparable with finely sculptured Recent specimens; GS2946, lower part of Calamity Point Sandstone, east side of Calamity Point, Clifden, Southland, complete small valve in concretion (interior visible only, ribbing not compared with Recent specimens).

Clifdenian (Middle Miocene): GS7695, lower part of Slip Point Siltstone between Long Beach and Slip Point, Clifden, Southland, one slightly crushed valve closely comparable with Recent specimens.

Tongaporutuan (Upper Miocene): GS1217, Toe Toe Conglomerate, Tarata Hydroelectric Power Station, Ratipiko, 2km SE of Tarata, east of Stratford, two broken specimens in soft sandstone; GS7314, recollection of GS1217,

many complete, paired shells and internal moulds in hard conglomerate (ribbing, seen on GS 1217 frags. only, comparable with Recent specimens).

Opoitian (early-mid Pliocene): Umukiwi Shellbed, quarry below Umukiwi Trig. Station, Huiaroa, near Stratford, 1 large, narrow, very inflated, strongly ribbed valve (more inflated than any Recent ones seen, but similarly narrow Recent ones are known, and this probably falls within the range of variation of Recent specimens).

Waipipian (late Pliocene): GS4253, Upper Waipipi Shellbed, Waverley Beach, west of Wanganui, common as large, broad valves.

Mangapanian (latest Pliocene): GS4214, Wilkie's Shellbed, Wilkie's Bluff, mouth of Waitotara River, one typical valve; GS4213, Wilkie's Shellbed, Tokomaru East Road, inland from Wanganui-Hawera highway, 1 typical valve; coral thicket east of Lake Ferry, Palliser Bay, South Wairarapa, paired shell (recorded by Beu 1967, p.95, as "*Promantellum* n.sp. aff. *marwicki*", but ribbing is comparable with the most finely sculptured Recent specimens).

Nukumaruan (early Pleistocene): GS10844, reef near lighthouse, Castlepoint, east Wairarapa, 1 typical valve; GS10849, siltstone near top of hill, Devil's Elbow, 30km north of Napier, Hawke's Bay, valves common; M.42738, shellbed N. bank Mangahao R. 1 mile S. of Mangahao, N. Wairarapa, N149/265240, B. A. Marshall Colln., National Museum, many fragmentary; GS5438 & GS5439, Okau-awa Stream, Kereru Road, central Hawke's Bay, valves uncommon.

Castlecliffian (Putikian Substage) (late lower Pleistocene). Recorded by Fleming (1953) from the following localities and formations at Wanganui: Kupe Formation, Gastropod shellbed: GS4121; pelecypod shellbed: GS4041, GS4045, GS4048, GS 4118; Lower Castlecliff Shellbed: GS4028, GS4033, GS4104, GS4140, GS4231, GS3104; Pinnacle Sand: GS4025; Tainui Shellbed: GS4013, GS4026 (valves are common in this formation); Upper Castlecliff Shellbed: GS4008, GS4185; lowest outcrop of Landguard Sand at Landguard Bluff: GS4033. Other Putikian localities: Te Piki, Cape Runaway, valves common in several N.Z. Geological Survey collections, recorded by Powell (1934, p.263), and in B. A. Marshall Colln., National Museum (M.40130); M.42965, below old reservoir in stream, foot of hill Whakatane-Ohope Road, Ohope Beach, Bay of Plenty, B. A. Marshall Colln., National Museum, 1 valve plus frags.

FEW OR MANY INVASIONS?

Grange (1974, p.13) recorded specimens of *Limaria orientalis* living in 10m of water off Tiritiri Island, Hauraki Gulf, and in 5m off Goat Island, Leigh. If it has previously lived commonly in these depths, it would be expected to occur at a greater range of New Zealand fossil localities than it is known at. There are a large number of Oligocene to Pleistocene fossil localities in New Zealand where *L. orientalis* would be expected to occur if it had lived in the New Zealand area consistently from Oligocene time until relatively recently, and in particular it would be expected to occur in many more beds than it does in the Wanganui coastal section, such as the Waipipi shellbeds below the upper one, the Tewkesbury Formation, the Kaimatira Pumice Sand, the Shakespeare Cliff Sand, and the Putiki Shellbed. Indeed the species is absent from all Nukumaruan and Okehuan (lower Castlecliffian) beds at Wanganui. This could

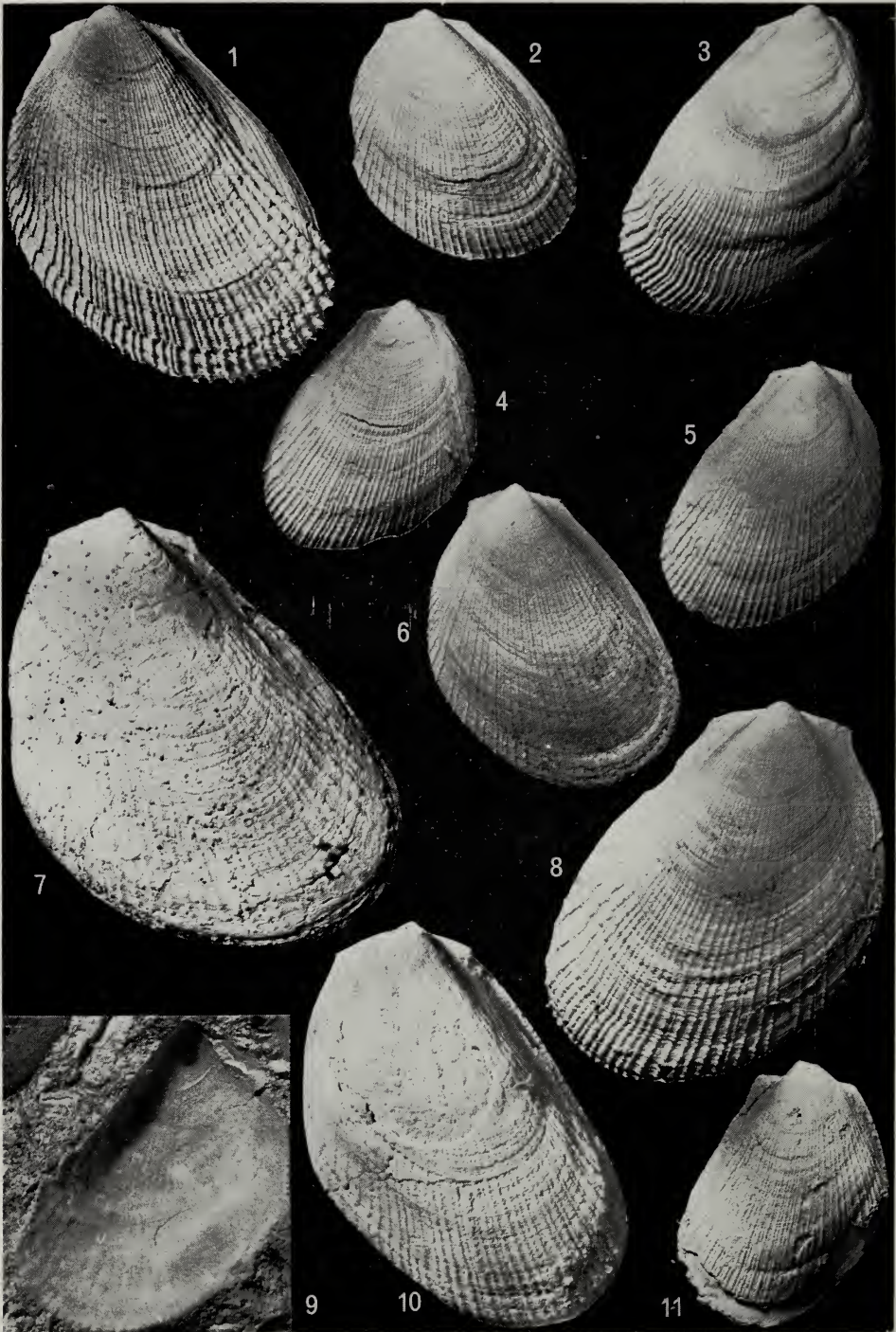


Plate 1

be interpreted as supporting the contention that *Limaria orientalis* became extinct and reinvaded the New Zealand area frequently.

However, the species is known in Wairarapa and Hawke's Bay at several Nukumaruan localities, spanning most of the stage, when it appears to have been absent from Wanganui area. This suggests that *L. orientalis* is so uncommon outside its usual intertidal environment that it is not commonly found fossil in beds that were deposited far below low tide. However, siltstone with *L. orientalis* at five of the 35 localities recorded above (Pakaurangi Pt.; GS9500, Oamaru; GS7695, Clifden; Lake Ferry coral thicket; GS10849, Devil's Elbow) was deposited in mid-continental shelf conditions or in even deeper water, showing that *L. orientalis* occasionally lives well below low tide mark. The thinness and fragility of the shells, and consequently frequent breakage before fossilisation, must be taken into account, as must the fragility of the shells once they are deposited in the rock, and consequent difficulty of collection. At Wanganui, shells of *L. orientalis* are so thin and fragile that they are difficult to see in an outcrop unless they are exposed almost parallel to the face, and it seems likely that specimens will eventually be collected at many more localities than they are known from at present.

For any other species having a markedly discontinuous time range, and in which frequent extinctions and reinvasions in the New Zealand area would not be envisaged (for instance, *Dosinia (Asa) lambata* Gould), the incomplete fossil record shown in Fig. 12 would have been taken to indicate that the environment in which the shell lived was preserved too infrequently in the fossil record for the species to have a complete history. In the case of *Limaria orientalis*, which has just successfully complete a migration to New Zealand, it is impossible to distinguish in the fossil record the results of the two possible causes of such a discontinuous record: poor preservation of a near-shore habitat, and frequent extinction and reinvasion. However, some idea of which of these is the more likely cause can be sought in the sea temperatures indicated by the other fossils with which *Limaria orientalis* occurs at various times during the Cenozoic. New Zealand Cenozoic sea temperatures have been the subject of many recent studies, summarised by Hornibrook (1971). They were markedly higher than at present for most of the Tertiary time, and fell markedly below present temperatures only during the rapid fluctuations of temperature that occurred during the Pleistocene. Therefore there seems to be no reason why, once *Limaria orientalis* reached New Zealand, presumably during Oligocene time, it should have become extinct here until the first Pleistocene glacial phase. Indeed the scattered occurrence of specimens through most rocks of Pleistocene and late Pliocene age suggests that temperatures fell too low for the survival of *Limaria orientalis* for short periods only. One possible period when its absence may have been caused by low temperatures was during the Okehan (earlier Castlecliffian substage) as this has consistently been interpreted as a cool period.

In summary, it seems likely that *Limaria orientalis* inhabited the New Zealand area continuously from the Oligocene until early Pleistocene time, and that its discontinuous record is almost entirely due to its very shallow habitat. Presumably it became extinct here and migrated back several times during Pleistocene time, in response to falling and rising glacial and interglacial sea temperatures. If so, its discontinuous Pleistocene record probably results from a combination of its shallow habitat and frequent extinction and reinvasion. Such a Pleistocene history would mean the species has a long pelagic larval life, so that larvae are frequently carried in currents to the New Zealand area, and were able to develop into adults whenever the sea temperatures around New Zealand

were above the species' threshold level for growth. Presumably an invasion of long enough duration to appear in the fossil record could occur whenever the sea temperature reached a slightly higher level, above the species' reproduction threshold. It seems likely that the appearance of *Limaria orientalis* in New Zealand during 1972 was caused merely by a natural influx of pelagic larvae to an area the species had occupied for much of Cenozoic time, and that since the last glaciation it was only during 1972 that its threshold temperature for reproduction was exceeded in north-eastern New Zealand waters.

ACKNOWLEDGEMENTS

I wish to thank Mr J. R. Penniket for information on *Limaria orientalis* in Northland, and Drs C. A. Fleming and P. A. Maxwell, N.Z. Geological Survey, for comments on the manuscript. Photographs are by D. L. Homer, N.Z. Geological Survey.

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A NEW FLAMMULINID LAND SNAIL FROM THE NORTHERN BLOCK OF NORTHLAND (ENDODONTIDAE: PHENACOHELICINAE)

By N. W. Gardner

Abstract

A new land snail, *Flammulina tepakiensis* (Endodontidae: Phenacohelicinae) from bush remnants in the Far North of the North Island is described.

Introduction

While no species of *Flammulina* have so far appeared in the faunal lists of land snails taken from this northernmost region of the North Island, two species are now known to occur there, and one, a new species is named below. This relatively rare snail appears to be restricted to the small isolated areas of bush on a few of the higher ridges.

The vegetation around the type locality has been greatly modified by repeated burning off, with the original bush cover now reduced to the sides of steep gullies which are isolated by the spread of the thorn bush *Hakea*. Continued searching in this area since 1966, when a single example was found, has now produced sufficient material to warrant description.

Family ENDODONTIDAE. Pilsbry 1894.

Subfamily PHENACOHELICINAE Suter 1892.

Genus *Flammulina* Martens 1873.

Flammulina Tepakiensis. Gardner n. sp. Plate 1. figs. 1-5.

Shell small, turbiniform, imperforate, of three and a half whorls. Protoconch of one and a half finely sculptured whorls, having initially some nine or ten faint spirals with the addition of oblique radials on the last whorl (Fig. 5). Junction of protoconch and teleoconch distinct, the latter having only low weak axial sculpture. Whorls rounded, body whorl above the periphery and near the aperture a little depressed; spire half height of aperture. Shell of a straw colour with no colour markings. Sculpture consists of low rounded weak axial ribs, some ten per mm., extending from suture to below the periphery where they weaken and fade out.

The whole surface of shell finely punctuate. Some specimens have a few weak intermittent incised spirals around the base. Suture strongly impressed. There is no perforation and around the umbilical region and the parietal wall there is a whitish glaze.

Aperture lunate, outer lip a little depressed laterally, columella oblique but straightening up just below its junction with body whorl. The weak riblets are visible through the shell from within the aperture. Animal comparatively large,

jet black, foot large. The brown and gray mottled visceral mass shows through shell.

Diameter 5.4mm. Height 3.0mm.

Radula teeth: (Fig. 5) with the formula: 18 x 9 x 1 x 9 x 18.

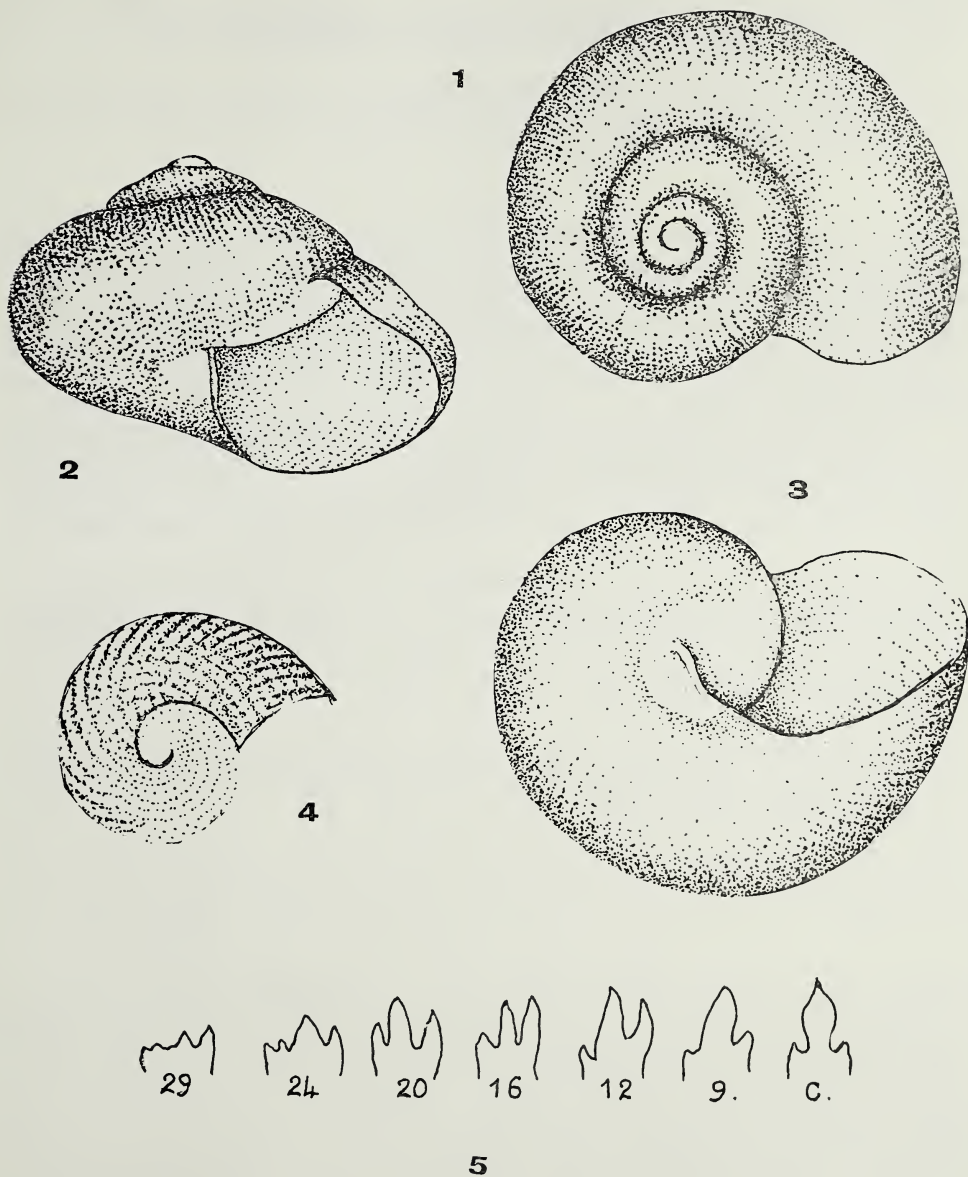


Plate 1. *Flammulina tepakiensis* Gardner n.sp.

Figs. 1 to 3, adult shell; fig. 4, Sculpture of protoconch; fig. 5, radula.

Central and laterals tricuspid, mesocone pendulous with evenly produced side cusps, bases narrow. Central about same size as laterals.

Marginals of varying shape, tricuspid at first, oblique, with endocone larger than entocone, base wider than in laterals. Fourteenth to seventeenth marginal with four cusps, the outer two smaller. Following teeth smaller and weakly developed.

Type material: Holotype in Auckland War Memorial Museum.

Paratype, National Museum, Wellington.

Type locality: Leaf litter, copses of bush, ridge west of Pandora Trig, Far North of North Island. -1-66 to 2-1-74. N.G.

Remarks

This species is provisionally placed in the polytypic genus *Flammulina* Martens 1873 and a discordant feature is noted: The genotype, *Flammulina zebra* Le Guillou (*pholophora* Pfr) has a smooth featureless protoconch, but the protoconch of this new species is spirally lined initially with the addition oblique axial sculpture later. This feature allies it to *Flammulina albozonata* Gardner which occurs some distance further south on the larger 'Pliocene island' of central Northland (Climo 1973).

Only a single example of the second species of *Flammulina* from this area is at present available, but this is undoubtedly *F. perdita* (Hutton). Compared with other northland specimens, this shell differs only in having a reddish tinge instead of the usual pale horny colour, and in having a slightly smaller umbilicus.

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A MACRO — AND MICROSCOPIC EXAMINATION OF *BULLA QUOYII* GRAY IN DIEFFENBACH (MOLLUSCA: OPISTHOBRANCHIA)

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INTRODUCTION

The name of the common New Zealand "Olive Bubble Shell", which has been called *Quibulla quoyi* (Gray, 1843) since 1946 (Powell, 1946 *et seq.*; Morton & Miller, 1968; Penniket, 1970; Rudman, 1971a) must be amended to *Bulla quoyii* Gray in Dieffenbach, 1843. The reasons for this alteration are given in a separate paper (Willan, in prep.). This present work examines the species on two levels: firstly the various different forms taken by this species in New Zealand are described; secondly results of a study on shell sculpture and radular structure using the scanning electron microscope (SEM) are presented.

THE SHELL

General Description. The shell of *Bulla quoyii* is thin and light. In New Zealand material adult size varies from 15-45mm. There is a deep and perspective apical cavity which reveals 4½-5 sunken teloconch whorls and the top of the outer lip rises above this level.

There is a crescentic whitish columellar callus which is applied closely to the base of the columella without leaving any discernable umbilical chink, an opaque whitish glaze which is continuous with the callus basally extends the length of the parietal wall. Generally the shell is mottled in light brown and white, sometimes the white markings merge to form irregular longitudinal white areas (Plate 1e). Most often three darker spiral bands are visible and there may be a fourth towards the apex (Plate 1g). The mouth is streaked with white although the extreme edge of the outer lip is light brown, deep within the aperture a mottled pattern predominates. Live shells are covered with an orange-brown periostracum which occasionally takes on a rusty colour.

Shell Shape. Shape is exceedingly variable. *Bulla quoyii* covers the entire range of form from small globose shells (Plate 1, c, d) through to large elongate shells (Plate 1, a, b). The outer lip rises above the spire and is straight or moderately convex, the base of the shell is generally wider than the apex. Shell shape appears to be correlated with environment; shells from sheltered localities (e.g. Houhora Harbour, Whangateau Harbour) tend to be large and elongate whereas shells from open coastal situations (e.g. Cape Maria van Diemen, Bland Bay, Goat Island Bay) tend to be smaller and more globose. Plate 1 shows the range of shell shape for *Bulla quoyii*.

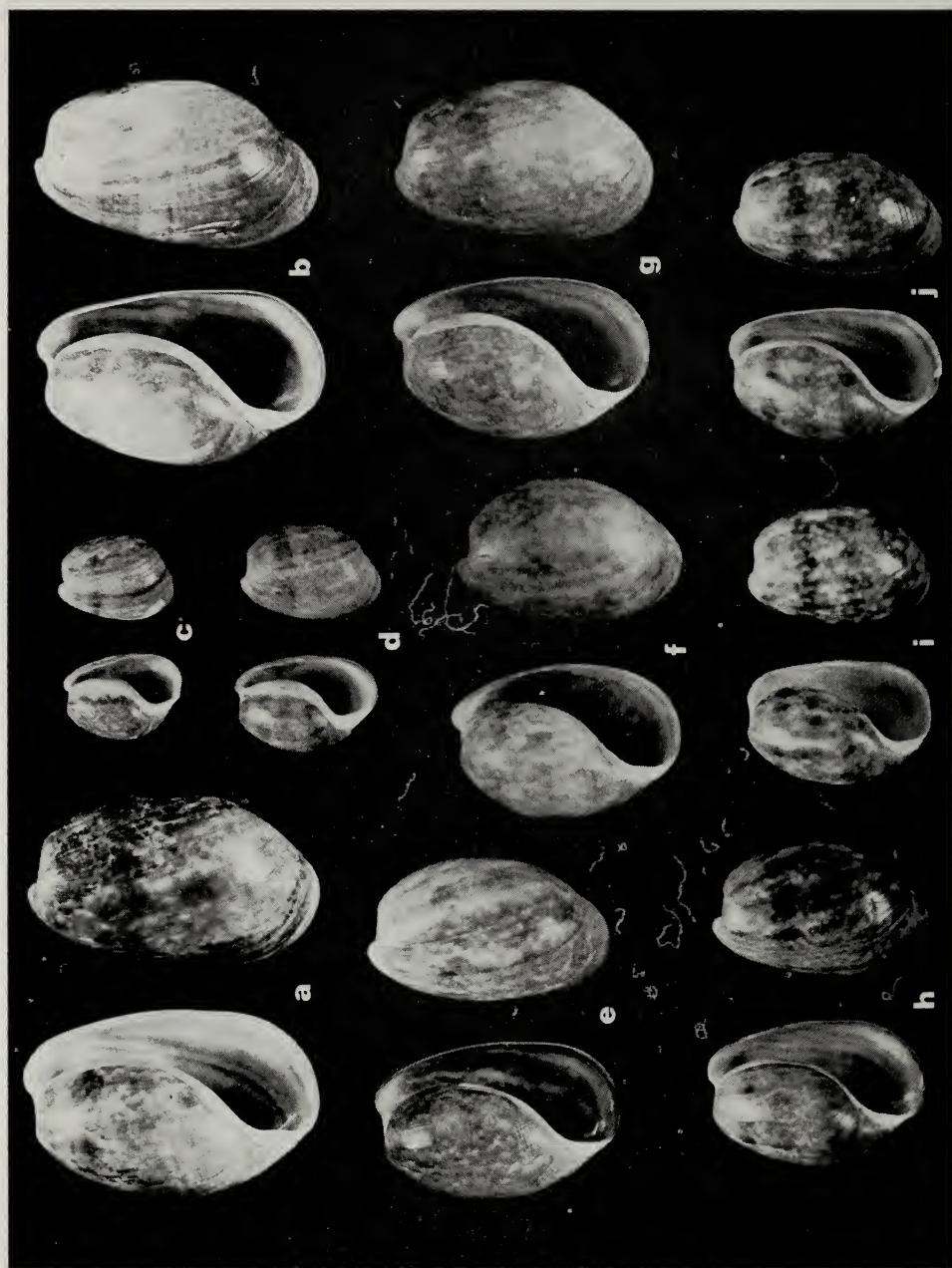


Plate 1. Variation in shell shape in *Bulla quoyii*: a, Marsden Point, Whangarei Heads; b, Mahurangi Heads West; c and d, Goat Island Bay, Leigh; e, The Lagoon, near Cape Karikari; f, Paxton Point, Great Exhibition Bay; g, Kohotutea Point, Cape Karikari; h and i, Goat Island Bay, Leigh; j, Ti Point, Leigh (approximate natural size).

Apical Cavity. The sunken spire of *Bulla quoyii* can be easily examined with the SEM (Plate 3a) because of its large size and open perspective nature. Considerable sculptural detail is present on the spire whorls. At the extreme apex is the minute, smooth protoconch which resembles a flattened disc. Sculpture on the first $1\frac{1}{2}$ whorls is of smooth, oblique axial ribs, 30-35 per whorl. Beyond the first $1\frac{1}{2}$ whorls these ribs are replaced by a series of continuous incised spiral lines. There is only a single line when they first appear after one whorl, this spiral bisects the axial ribs. There are however 4-5 spiral lines on the final spire whorl. Weak irregular axial growth striae are present between the spiral lines over most of the spire whorls, but on the last whorl they are more conspicuous and closer together and appear almost lamellate. As the spiral lines interrupt these axial lamellae the sculpture has an almost scalariform appearance on the last whorl (Plate 2a).

Spiral Lines. The basal third of the shell has 9-24 close, spirally incised lines which are most numerous at the very base. These lines become faint on the last half whorl of adult shells, and here the upper lines may become obsolete altogether.

When examined with the SEM (Plate 2d), these apparently continuous spiral lines resolve into rows of discrete, oblique, overlapping punctae which are oriented at an oblique angle to the longitudinal axis of the shell. The punctae are elongate and parallel-sided, being deepest on the side farthest from the lip and shallowest on the side nearest to the lip. The overall appearance is like that of a series of overlapping gouges made with a chisel operated in a direction away from the lip. The punctae closest to the anterior end of the shell (upper edge, Plate 2d) are deep, truncated and close together hence the spiral lines appear strongest here; the punctae forming the rows closest to the middle of the shell (lower edge, Plate 2d) are shallower and drawn out, with a considerably greater overlap, hence the spiral lines here are rather weak. The floor of each punctation is generally smooth, although some show two slanting ridges. These rows of oblique punctae are probably homologous with the spiral rows of punctae which constitute the sculpture of the Acteonidae, for example: *Pupa kirki* (Hutton); *Pupa sulcata* (Gmelin) and *Pupa alveolata* (Souverbie) (Cernohorsky, 1972); *Bullina* spp. (Rudman, 1971a); *Maxacteon* spp. (Rudman, 1971c).

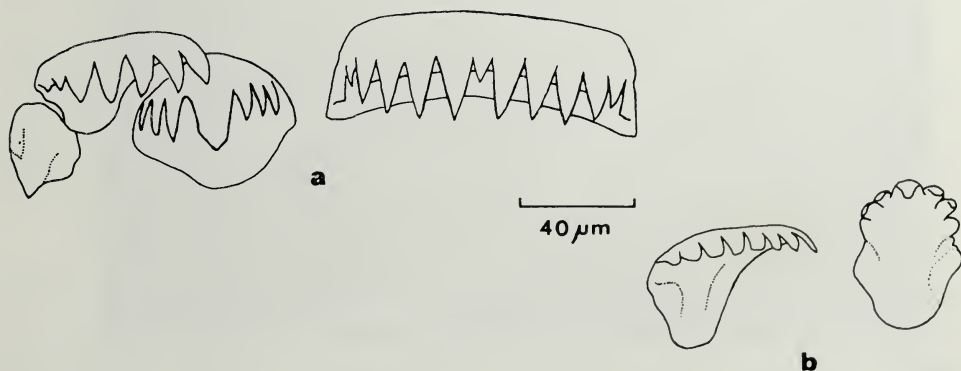


Figure 1. Radula of *Bulla quoyii* as seen with light microscope.



Plate 2. *Bulla quoyii*, scanning electron micrographs; a, scalariform sculpture in apex (x 100); b and c, locations of areas on the shell examined with the SEM; d, spiral sculpture on base (x 100).

RADULA

The radula of *Bulla quoyii* has been examined both with the light microscope (Fig. 1) and the SEM (Plate 3c). The radula has a formula of 22-24 x 1.2.1.2.1. for adult specimens. The rachidian is large, rectangular and curves upwards away from the horizontal plane. With the light microscope the sides appear to be sharply cut off, however the SEM shows that the outer edges curve upwards to stand nearly perpendicularly to the longitudinal axis of the tooth. There is a small retracted, triangular, central cusp which was not mentioned by Rudman (1971a), and this is flanked symmetrically with 5 or 6 elongate and straight, sharp denticles which resemble the teeth of a comb, all the denticles except the outermost ones are longer than the central cusp.

The inner lateral teeth stand above the rachidian, there is a straight-sided central cusp which ends rather abruptly at a sharp point. On either side of this cusp are 3 or 4 symmetrical denticles which decrease progressively in size, these denticles are narrower than the central cusp and taper gradually towards their tips. The denticles of both the inner and outer lateral teeth are recurved. Regrettably most of the cusps and denticles on the inner lateral teeth in Plate 3c have become broken towards their bases during the scanning process.

The outer lateral teeth are asymmetric with a graduated series of 5 to 7 denticles, the largest are elongate and closest to the midline of the radula. These denticles are close to each other, they have rounded tips.

The marginal teeth are small and triangular, they have a weak denticle which faces the growing end of the radula.

Rudman (1971a) has adequately described the gizzard plates, and elsewhere, the reproductive system (including penial details) of *Bulla quoyii* (Rudman, 1970).

CONCLUSIONS

A consideration of the details of the microsculpture in *Bulla quoyii* becomes very significant in trying to group the *Bulla* species and in interpreting their phylogeny. I shall consider separately the importance of the two components of microsculpture which have been described in this paper (*i.e.* incised spirals on the whorls of the involute apical cavity and spiral lines encircling the base of the shell).

Considering firstly the spirals in the apical cavity, this pattern of sculpture is found not only in *B. quoyii*, but also these spirals are present in every one of 7 other species of *Bulla* from all over the world that I have examined carefully and they are remarkably consistent in appearance in every species. The species I have examined are: *B. ampulla* Linnaeus; *B. angasi* Pilsbry (= *B. subtropicalis* Powell); *B. gouldiana* Pilsbry; *B. occidentalis* A. Adams in Sowerby; *B. punctulata* A. Adams in Sowerby; *B. striata* Bruguiere; *B. vernicosa* Gould.

There is no reason to suppose that other *Bulla* species yet to be examined would lack spiral sculpture of this sort. It seems improbable to suggest that such similar sculpture could have evolved separately in 8 species and it is more realistic to consider that this sculpture inside the apical cavity is an ancestral character that has been retained by all the recent descendant species no matter how far other conchological characters have diverged. This then leads one to postulate an adaptive advantage which possession of this character must bestow to the involute shells of *Bulla* species. Perhaps this sculpture could help to maintain

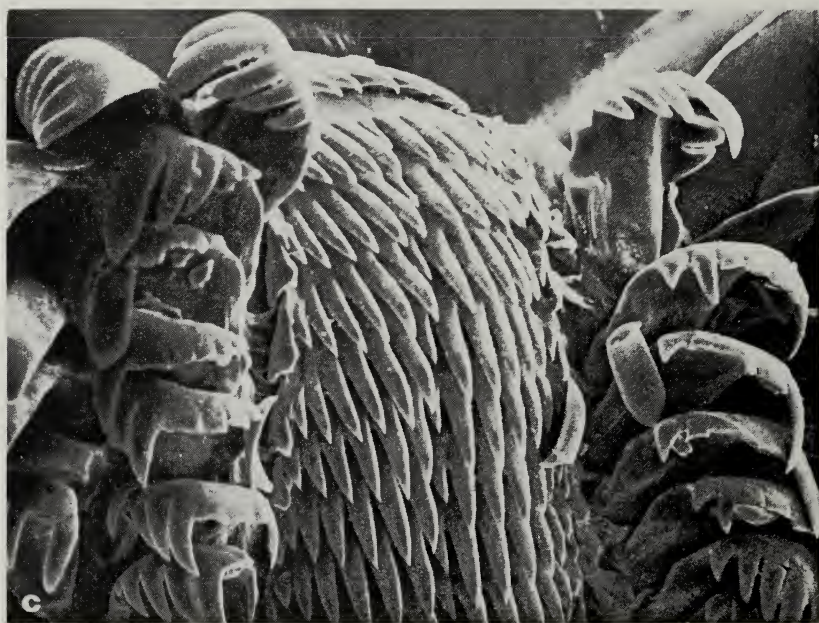
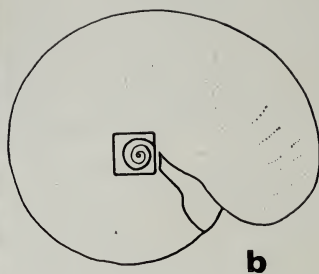
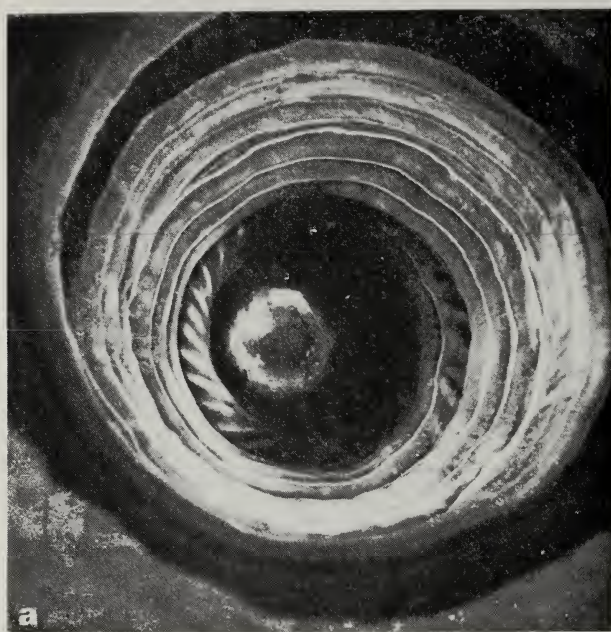


Plate 3. a, sculpture in apical cavity (x 150); b, location of SEM photograph; c, radula SEM (x 125).

water circulation on a microscale inside the apical cavity to prevent accumulation of stagnant water or faecial material since the anus is situated close to this apical cavity (Rudman, 1971a). Or perhaps this sculpture is inimical to larvae of encrusting organisms that could possibly settle in the "shelter" of the apical cavity and subsequently extend outwards to overgrow the exterior of the shell. At least it is reasonably certain that this sculptural element is a property of the genus *Bulla* as a whole and is accordingly of little value in specific determinations.

The second sculptural component to consider is the basal spirals; although consistently present in New Zealand populations of *B. quoyii* these spirals are much fainter on the last half whorl and in some Australian specimens are obsolete in this region. Their number is also subject to a very wide variation from shell to shell (9-24). No other Pacific *Bulla* species has such basal sculpture although *B. striata* Bruguiere from Florida and the West Indies also has these spiral lines on the base. I would consider these spiral lines as reflecting an ancestral condition in which the whole exterior of the shell was sculptured with rows of spiral punctations and now in *B. quoyii* the existing spirals represent a restriction to those on the base only and suppression of spirals on the middle and upper parts of the whorls.

ACKNOWLEDGEMENTS

I am very grateful to Mrs H. Roberts and Mr G. Batt, Zoology Department, University of Auckland for assistance with the SEM's and preparation of Plate 1 respectively.

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A STUDY OF *SCUTUS ANTIPODES* MONTFORT (GASTROPODA: FISSURELLIDAE)

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Abstract

A study of *Scutus* based on 138 specimens from New Zealand and East Australia, has shown that the New Zealand populations previously known as *Scutus breviculus* (Blainville, 1817), cannot be satisfactorily separated from the Australian populations on either a single or combined, constant diagnostic character, and that they both should be combined under the earliest applicable taxon of *Scutus antipodes* Montfort, 1810.

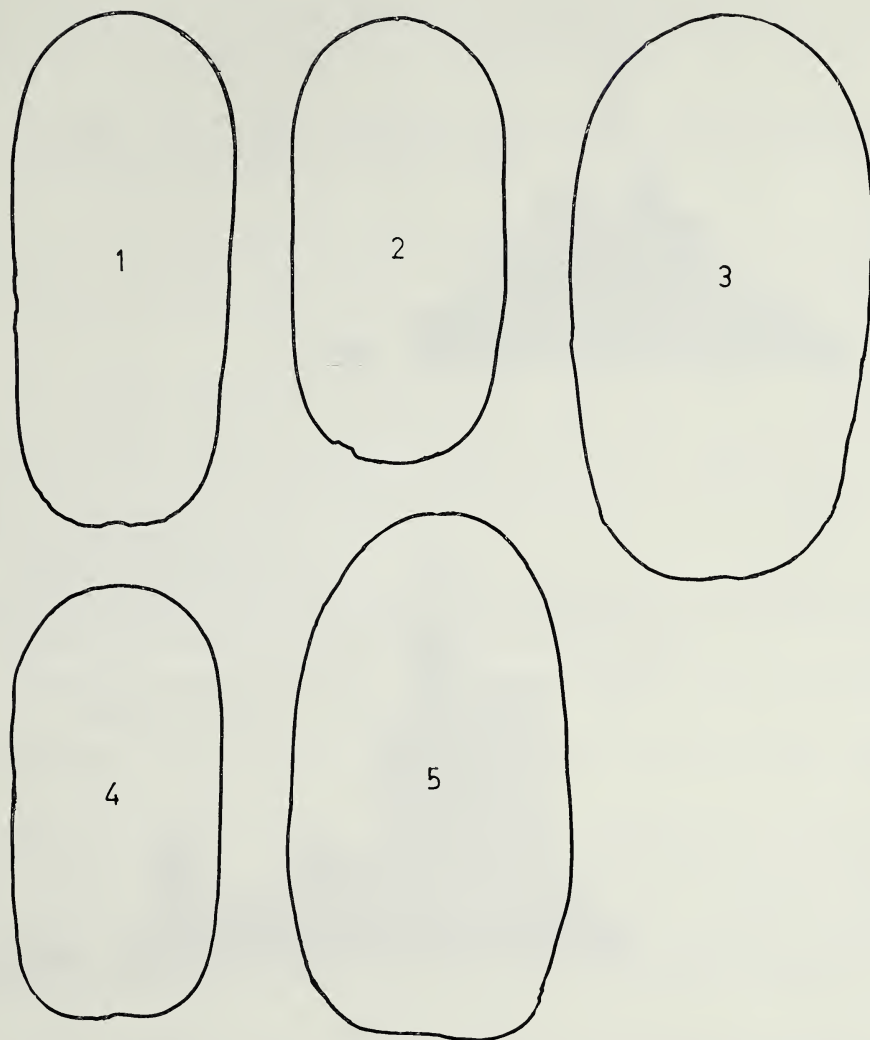
History of the species

The species was first described and illustrated by Chemnitz (1795), who stated that the specimen he examined was unique in Schumacher's collection, and had been borrowed by him for description and illustration. Chemnitz was not quite certain whether he was dealing with a "true *Patella*" or with "one valve of a bivalve shell". His figure, although correct in relationship of ratio of length:width, has been badly executed. The specimen came from unknown locality but Chemnitz presumed that it originated in the East Indies.

Montfort (1810) who renamed species previously already described without giving reasons for doing so, provided the name *Scutus antipodes* for a species he questionably referred to "*Patella ambigua* Chemnitz" and to "*Patella elongata* Lamarck (1803)", the latter a fossil from Grignon, Paris Eocene. The stated locality was "New Zealand" and the figure given by Montfort shows a slender individual with a width-index (width:length) of 45%. Provided of course that Montfort's figure has been accurately drawn, then his specimen originated in Australia since such slender individuals have not as yet been recorded from New Zealand. It is quite probable, however, that no great stress has been placed on the correct dimensions of the specimen by the artist, a common failing of the day, and that Montfort's locality of "New Zealand" is correct.

Dillwyn (1817) was the first author to validate Chemnitz's non-binomial *Patella ambigua*, but in doing so, he created a primary homonym to *P.ambigua* Gmelin, 1791, from the Arctic Seas. Dillwyn's locality for his *P.ambigua* was "coasts of New Holland" (= Australia).

Blainville in 1817 renamed the genus *Parmophorus* and described *P.breviculus* from unknown locality. It is the latter taxon which in the last 50 years has been applied to New Zealand populations of *Scutus antipodes*. Blainville also described a *Parmophorus elongatus* which he incorrectly credited to Chemnitz and which refers to Australian populations of *S.antipodes*.



Figs. 1-5. Variation in outline of *Scutus antipodes* Montfort. (Nat. size).

1. Phillip I., Victoria, Australia; 67.3mm x 29.2mm = W.I. 43%.
2. Maroubra, N.S.W., Australia; 58.6mm x 28.6mm = W.I. 49%.
3. Bradley's Head, N.S.W., Australia; 74.6mm x 40.1mm = W.I. 54%.
4. Manukau Harbour, Auckland New Zealand; 57.5mm x 27.8mm = W.I. 48%.
5. Timaru, New Zealand; 68.0mm x 37.5mm = W.I. 55%.

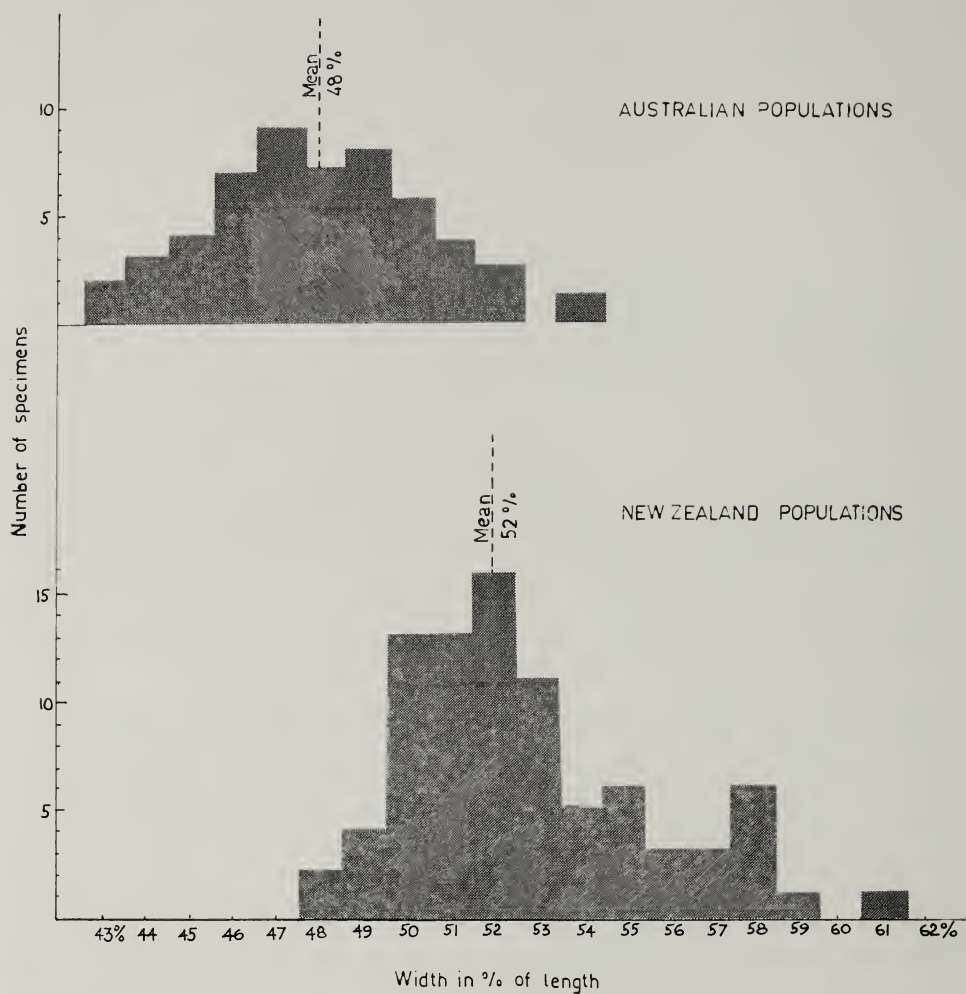


Fig. 6. Width-frequency histogram of *Scutus antipodes* Montfort, from Australia and New Zealand.

Schumacher (1817) was not particularly pleased with the way the artist drew his specimen of "*Patella ambigua*" in Chemnitz's work (*op.cit.*), and he re-illustrated the specimen in his own work on plate 22, figs. a-c under the name *Patella unguis* Linnaeus.

Lamarck (1822) changed Blainville's *Parmophorus elongatus* to *P. australis* for which he cited Chemnitz's *Patella ambigua* and *Scutus antipodes* Montfort. He gave the locality as "New Holland and New Zealand".

A. Adams' (1853) treatment was most unsatisfactory: *Patella ambigua* Chemnitz, *Scutus antipodes* Montfort, and *Parmophorus australis* Lamarck, were synonymised with the tropical Indo-Pacific *Scutus unguis* (Linnaeus), and the Recent East Australian *Scutus* was considered conspecific with the Paris Basin Eocene *S. elongatus* (Lamarck, 1803).

E. A. Smith (1879) published a revision of *Scutus* in which he considered "*Scutus ambiguus* Chemnitz" conspecific with *S. antipodes* Montfort and *Parmophorus breviculus* Blainville, and endemic to New Zealand. The Australian population Smith separated under the name *Scutus anatinus* (Donovan), and he remarked that the New Zealand populations of *S. antipodes* are easily distinguished from the Australian *S. anatinus* by its considerably shorter form and the squarish truncate anterior end.

Pilsbry (1890) followed Smith's (*op.cit.*) interpretation by allocating *Scutus ambiguus* Chemnitz with its synonym *S. antipodes* Montfort, to the New Zealand populations and applying the following differentiating criteria:

anatinus (Australia): shell more elongate, ends rounded, front end somewhat sinuous, not squarely truncated.

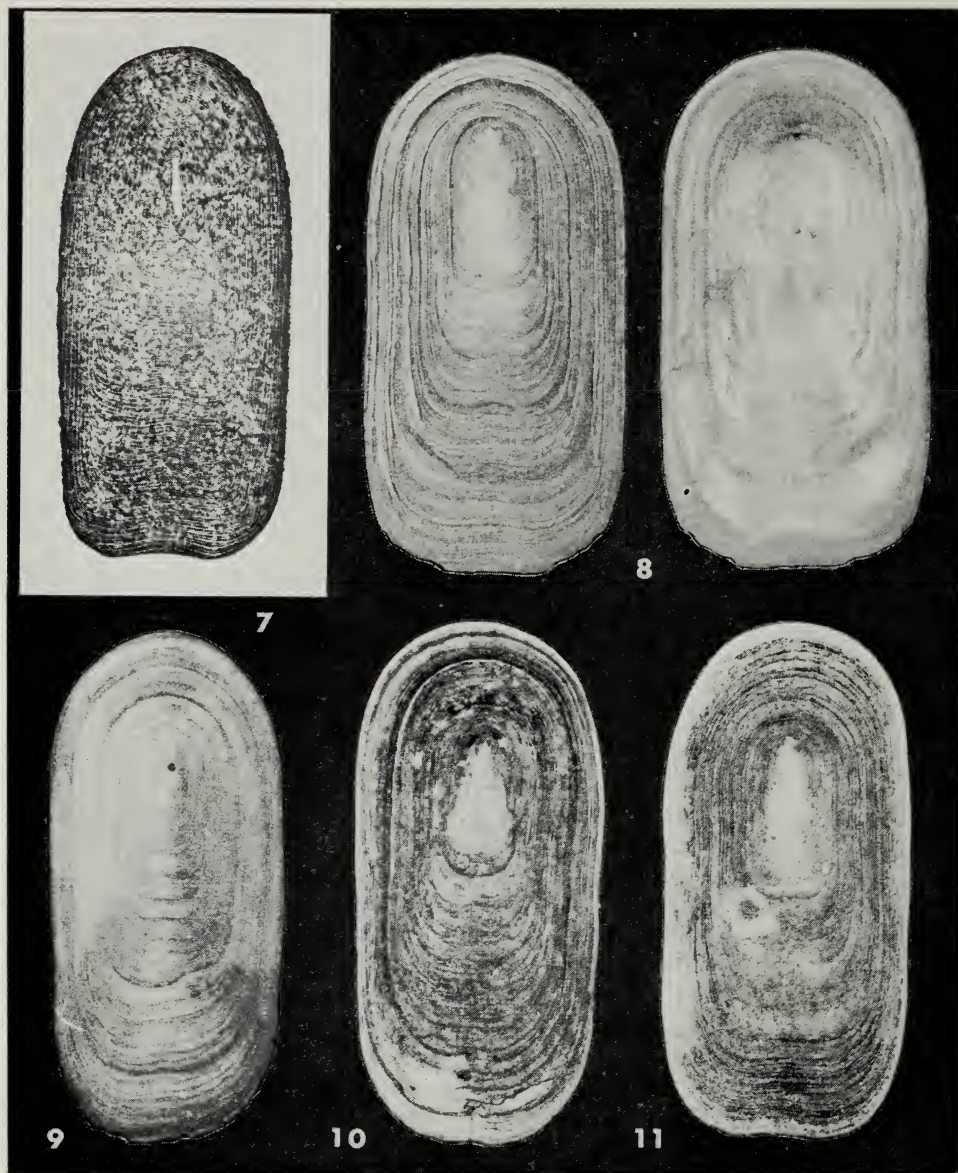
ambiguus (New Zealand): shell shorter than *S. anatinus*, front margin squarely truncated.

Suter (1913) followed E. A. Smith (*op.cit.*) and Pilsbry (*op.cit.*) in considering *ambiguus*, *antipodes* and *breviculus* conspecific and living in New Zealand.

Hedley (1917) placed great stress on the accuracy of Montfort's drawn type-figure of *Scutus antipodes* and concluded that the name is applicable to the East Australian populations of *Scutus* previously called *S. anatinus* (Donovan, 1820), and suggested that *S. breviculus* (Blainville) is the New Zealand *Scutus* with the broader shell.

Since three authors have stated that Australian and New Zealand populations are clearly distinguishable in characters of broad and narrow shell-form, we have made a morphometric study of 53 Australian and 85 New Zealand specimens, by measuring the length and width and expressing the width-index (W.I.) in % = width over length. At the same time, the position of the apex in relation to the posterior margin was measured and expressed in a percentage of the length of distance from the posterior margin (=A.I.). The higher the A.I. figure, the closer the apex is towards the centre of the shell. The results are as follows:

	Number of specimens	Length of specimens	W.I.	A.I.
Australia	53	19.2 - 91.5mm	43%-54%	17%-31%
New Zealand	85	22.8 - 76.0mm	48%-61%	16%-33%
		Overlap	48%-54%	



Figs. 7-11 *Scutus antipodes* Montfort. 7. Type-figure from Montfort, 1810, p.58. 8. Dorsal and ventral view of holotype of *Parmophorus breviculus* Blainville; BMNH, length 25.5mm. 9. Holotype of *Patella ambigua* Dillwyn; Zool.Mus. Copenhagen, length 55.1mm. 10. Specimen of *Scutus antipodes* Montfort from Bradley's Head, N.S.W., Australia; length 68.0mm. 11. Specimen from Motutara, Auckland, New Zealand; length 44.3mm.

Some interesting observations have emerged from this study: the Australian populations are slightly more slender (-5%) than New Zealand populations ($+7\%$), but there is a distinct zone of overlap of 65% of New Zealand and 53% of Australian specimens studied in the $48\%-54\%$ range. This 6% overlap in width-index represents about one-half of the total width-index fluctuation (11% and 13% respectively). We therefore had no difficulty in selecting New Zealand individuals which were as narrow as Australian specimens and *vice versa*.

The apical-index was virtually the same in both populations, but in smaller, younger specimens the apex was closer to the posterior margin than in larger, more adult individuals where the apex tended to shift away from the margin towards the centre but still sub-central (maximum one-third of total strength).

New Zealand populations, especially more senile individuals of the species, tended to have the anterior end slightly more sinuously excavated than Australian populations. However, even this character proved to be unreliable when specimens with a truncate or slightly excavated margin were found in both populations. We could not discern any other diagnostic difference which would aid in the separation of specimens of both populations without locality data.

Type specimens

Scutus antipodes Montfort, 1810: The type is no longer traceable, and the origin of Montfort's specimen remains equivocal depending on whether a greater stress is placed on his locality indication of "New Zealand" or the accuracy of dimensions of his type-figure drawing, i.e. length 85.0mm , width 38.5mm = W.I. 45% , which would place it as an Australian specimen.

Parmophorus breviculus Blainville, 1817: The holotype of this species is in the British Museum (Natural History), London, as E. A. Smith (*op.cit.*) correctly pointed out. The shell is complete with animal and preserved in spirits; it is a young individual, length 25.5mm , width 13.6mm = W.I. 53% ; this width-index could place it in either population.

Patella ambigua Dillwyn, 1817: It is only of academic interest that *Scutus breviculus* (Blainville, 1817) has chronological priority by a few months, since *P.ambigua* Dillwyn, 1817, is a primary homonym of *P.ambigua* Gmelin, 1791. The holotype of *P.ambigua* Dillwyn, is in the University Zoological Museum, Copenhagen, length 55.1mm , width 26.4mm = W.I. 48% . This width-index is just on the boarder of overlap between Australian and New Zealand populations.

Synonymy

Family Fissurellidae

Genus *Scutus* Montfort, 1810

Scutus Montfort, 1810. Conchyl.Syst. 2:58,59. Type species by OD

S.antipodes Montfort, 1810. Recent, Australia-New Zealand.

Scutus antipodes Montfort, 1810

- 1795. "*Patella ambigua*" Chemnitz, Syst.Conchyl.Cab. 11:181, pl. 197, fig. 1918 (non-binomial).
- 1810. *Scutus antipodes* Montfort, Conchyl.syst. 2:59, fig.opp.page; 1917 Hedley, Proc.Linn.Soc.N.S.W. 41:704,pl.47,figs.7-9.
- 1817. *Parmophorus breviculus* Blainville, Bull.Sci.Soc.Philom.Paris, p.28; 1825 Blainville, Dict.Sci.Nat.37:558.

1817. *Patella ambigua* Dillwyn, Desc.Cat.Rec.shells 2:1053 (refers to Chemnitz, *op.cit.*, fig. 1918, and also Humphrey's Conch. pl. 5, fig. 11) [non *P.ambigua* Gmelin, 1791].
1817. *Patella unguis* Schumacher (*pars*), Essai nouv. syst. p.179, pl. 22, figs. a-c only (non *Patella unguis* Linnaeus, 1758).
1820. *Patella anatina* Donovan in Rees, Encyclopaedia, Nat.Hist.Conch. 5:pl.16.
1822. *Parmophorus australis* Lamarck, Hit.nat.anim.s.vert. 6:5 (refers to Chemnitz, *op.cit.*, fig. 1918; *Scutus antipodes* Montfort and *elongatus* Blainville).
1879. *Scutis ambiguus* Chemnitz, E. A. Smith, J. Conch. 2:258, figs. 1-3; 1890 Pilsbry, Man. Conch. 12:289, pl. 40, figs. 9-11; 1913 Suter Man. N.Z. Moll. p. 103; 1915 Suter, Atlas, pl. 8, fig. 7.

Type localities: New Zealand (*S.antipodes*); coast of Australia (*P.ambigua*); none (*P.breviculus* and *P.anatina*); Australia and New Zealand (*P.australis*).

It is here concluded that individual specimens of New Zealand and Australian populations of *Scutus antipodes* Montfort, cannot be separated on the basis of any constant diagnostic character, and the species is regard as having an East Australian-New Zealand distribution.

Acknowledgements

I would like to thank Dr J. Knudsen, University Zoological Museum, Copenhagen, and Ms A. Blake, British Museum (Nat. Hist.), London, for the loan of the respective type-specimens of *Scutus ambiguus* and *S.breviculus*.

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CORRECTION TO THE NOMENCLATURE OF *BULLIA* (GASTROPODA: NASSARIIDAE)

By

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Abstract

The nomenclature of 6 South African and South American *Bullia* species is here revised.

Family NASSARIIDAE

Subfamily DORSANIINAE

Genus *Bullia* Gray in Griffith & Pidgeon, 1834

Bullia Gray in Griffith & Pidgeon, Anim.Kingd.Bar.Cuvier,Moll.&Rad. 12:pl.37, fig. 8. Type species by M *B.semiplicata* Gray in Griffith & Pidgeon, 1834 =? *Buccinum achatinum* Lamarck, 1816. Recent, Sth. Africa.

Bullia (Bullia) achatina (Lamarck, 1816)

1816 *Buccinum achatinum* Lamarck, Tabl.Encycl.Meth. p.2, pl. 300, figs. 4a, b.

1817 *Buccinum digitale* Dillwyn, Desc.cat.Rec.shells 2:646 (refers to Chemnitz, vol. 4, pl. 155, fig. 1468, 69 and pl. 157, fig. 1491) [coast of Bombay and Coromandel = error].

1840 *Leiodomus quoyii* Swainson, Treat,Malac. 12:302 (refers to Quoy & Gaimard, 1833, pl. 31, fig. 17).

1846 *Bullia semiflammea* Reeve, Conch.Icon. 3:pl. 3, sp.17.

1885 *Bullia capensis* Euthyme, Bull.Soc.malac.France 2:237 (Sth. Africa).

1915 *Bulla almo* Batsch, Bull.U.S.Nat.Mus. 91:54, pl. 35, fig. 4 (Pt. Alfred, Sth. Africa).

1921 *Bullia dulcis* Sowerby, Proc.Malac.Soc.Lond. 14:125, textfig. (Pt. Alfred, Sth. Africa).

Barnard (1959) and Kensley in Barnard (1974) credit the specific name *digitalis* to Meuschen, 1787, but Meuschen's "Museum Geversianum" is a non-binominal work which is not available for taxonomic purposes. *Bullia achatina* (Lamarck, 1816) is the first available name for this South African species.

Bullia (Bullia) callosa (Wood, 1828)

1828 *Buccinum callosum* Wood, Index Test. Suppl. pp. 12, 31, pl. 4, fig. 14a.



Fig. 1. *Bullia tranquebarica* (Roeding). Tulcar, Madagascar; 12.7mm x 6.0mm.

Barnard (*op. cit.*) credits the authorship of the species to both Gray and Reeve, while Kensley in Barnard (*op.cit.*) considers Gray to be the author. The actual author of this South African species is Wood.

Bullia (Bullia) tenuis (Reeve, 1946)

1846 *Bullia tenuis* Reeve, Conch.Icon. 3: pl. 1, sp. 1.

1915 *Erillia lara* Bartsch, U.S.Nat.Mus.Bull. 91:53, pl. 38, fig. 3 (Pt. Alfred, Sth. Africa).

Both Barnard (*op.cit.*) and Kensley in Barnard (*op.cit.*), credit the authorship to Gray, and Barnard adds to the confusion by citing for *tenuis* Wood, 1828, p. 12, and Gray, 1839, p. 128. *Buccinum tenue* Wood, 1828 (*non* Schroeter, 1805) on p. 12, is later listed as *Cassia tenuis* Wood, on page 33, and represents the West American species *Cassis (Cypraeacassis) tenuis* (Wood), while *Buccinum tenue* Gray, 1839, p. 128, is a species of *Volutopsius* Moerch, 1857, from Subarctic Seas.

Bullia (Bullia) tranquebarica (Roeding, 1798)

Fig. 1

1798 *Plotia tranquebarica* Roeding, Mus.Bolteniaum p. 96 (refers to Chemnitz, vol. 4, pl. 155, fig. 1463).

1825 *Terebra lineolata* Sowerby, Cat.shells coll. Tankerville App. p. 23 (refers to Chemnitz, *op.cit.*, pl. 155, fig. 1463).

- 1834 *Buccinum bellangeri* Kiener, Spec.gen.icon.coq.viv. 9:34, pl. 14, fig. 48 (also refers to Chemnitz, *op.cit.*, pl. 155, fig. 1463) [Bengal Seas and coast of Ceylon].

This Indian Ocean species is usually cited as *Bullia bellangeri* (Kiener) but two earlier names are available, and *B.tranquebarica* (Roeding) is chronologically prior. Since the latter name has been used by Crichton (1943), Roeding's taxon cannot be considered to be a *nomen oblitum*. The species lives in the Western Indian Ocean in an area extending from Madagascar to Ceylon and the Persian Gulf.

Subgenus *Buccinanops* d'Orbigny, 1841

Buccinanops d'Orbigny, 1841, Voy.Amer,merid.,Moll. p. 434. Type species by SD (Herrmannsen, 1846) *Buccinum cochlidium* Dillwyn, 1817. Recent, East coast of Sth. America.

Bullia (Buccinanops) cochlidium (Dillwyn, 1817)

- 1817 *Buccinum cochlidium* Dillwyn, Desc.cat.Rec.shells 2:627 (refers to Chemnitz, vol. 11, p. 275, pl. 209, figs. 2053, 54 [South Sea Islands = error]).
1834 *Buccinum lamarckii* Kiener, Spec.gen.icon.coq.viv. 9:5, pl. 3, fig. 6.

South American authors credit the authorship of *Buccinum cochlidium* to Chemnitz, but Martini and Chemnitz's work has been suppressed by the International Commission on Zoological Nomenclature as being non-binominal. *B.cochlidium* Dillwyn, 1817, is the first binomial erection for this species.

Bullia (Buccinanops) paytense (Kiener, 1834)

- 1832 *Buccinum squalidum* King & Broderip, Zool.Journ. 5:349 (non Gmelin, 1791).
1834 *Buccinum paytense* Kiener, Spec.gen.icon.coq.viv. 9:pl.6, fig. 16.
1846 *Buccinum citrixum* Reeve, Conch.Icon. 3:pl. 9, sp. 70.

The name *squalidum* is well entrenched in South American literature but *Buccinum squalidum* King & Broderip, 1832, is a primary homonym of *B.squalidum* Gmelin, 1791, and is therefore not available. *Bullia (Buccinanops) paytense* (Kiener, 1834) is the name to be used for this species.

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NOTE ON TWO PACIFIC GASTROPODS

By

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Abstract

A muricid protoconch is recorded in the Indo-Pacific buccinid species *Engina farinosa* (Gould) and the Japanese turbinellid species *Ceratoxancus teramachii* Kuroda, is now recorded from the Hawaiian Islands.

Family BUCCINIDAE

Genus *Engina* Gray, 1839

Engina Gray, 1839, Zool.Capt.Beechey's Voy. "Blossom", p. 112. Type species by SD (Gray, 1847) *E.zonata* Gray, 1839 = *Purpura turbinella* Kiener, 1836. Recent, Caribbean.

Engina farinosa (Gould, 1850)

Figs. 1, 3, 4

1850 *Buccinum (Polia) farinosum* Gould, Proc.Boston Soc.Nat.Hist. 3:152 (Kauai, Hawaiian I.).

1860 *Hindsia angicostata* Pease, Proc.Zool.Soc.Lond. p. 142 (Hawaiian I.).

1975 *Engina farinosa* (Gould), Cernohorsky, Rec.Auckland Inst.Mus. 12:190, figs. 40-42 (figd. holotype).

Specimens with the protoconch intact are rare and this may account for the absence of previous reports on the unusual shape of the protoconch. In *Engina farinosa* the protoconch is paucispiral, consisting of $1\frac{1}{2}$ smooth, angulate and slightly inturned whorls. This style of protoconch was previously unknown in the Buccinidae (Cernohorsky, 1971; Ponder 1972). The protoconch of *E.farinosa* is closely similar to the protoconchs of the muricid genus *Muricopsis* Bucquoy, Dautzenberg & Dollfus, and a similar protoconch has been illustrated by Ponder (1968) for *Muricopsis octogonus* (Quay & Gaimard). We concur with Robertson (1976) when he states that "it is clear that there is no justification for distinguishing genera based exclusively on protoconch differences". Although a muricid type of a protoconch in a buccinid genus might be considered unusual, it is well known that the Turridae contain an array of protoconch types which are also represented in the Nassariidae, Mitridae, Volutidae, etc.

Family TURBINELLIDAE

Genus *Ceratoxancus* Kuroda, 1952

Ceratoxancus Kuroda, 1952, Publ.Seto. Mar.Lab. 2(2):69. Type species by OD *C.teramachii* Kuroda, 1952. Recent, Japan.

Ceratoxancus teramachii Kuroda, 1952

Fig. 2

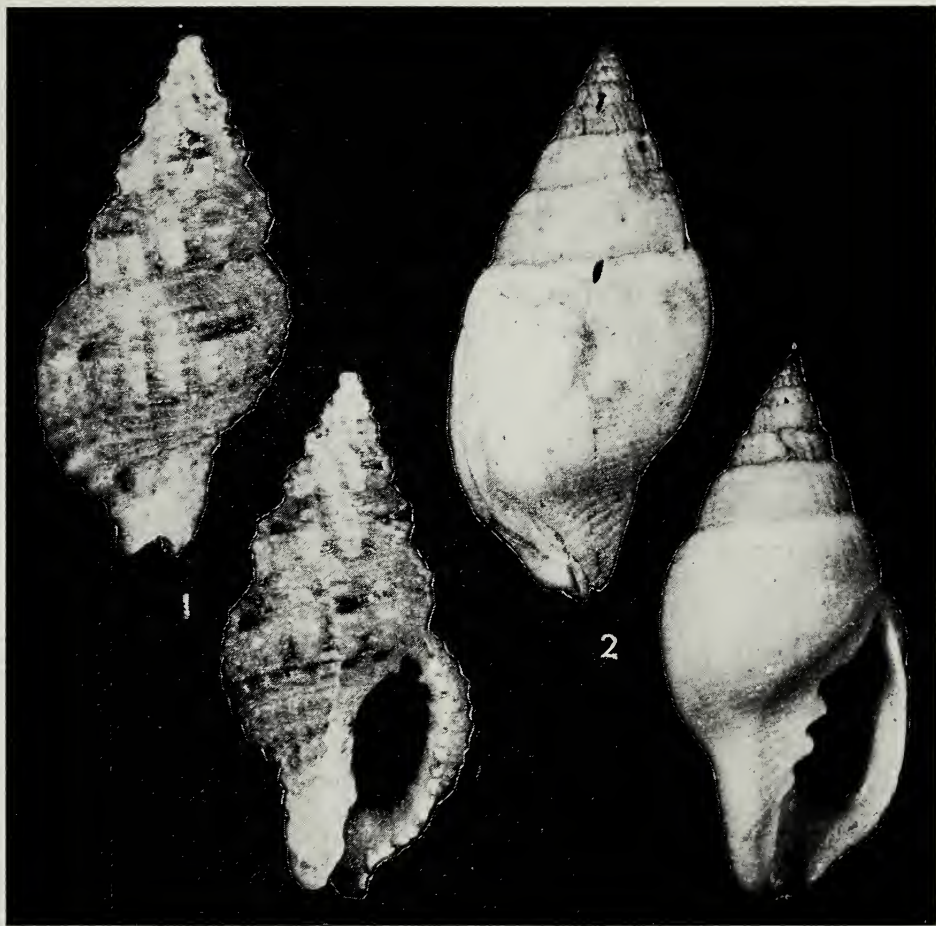
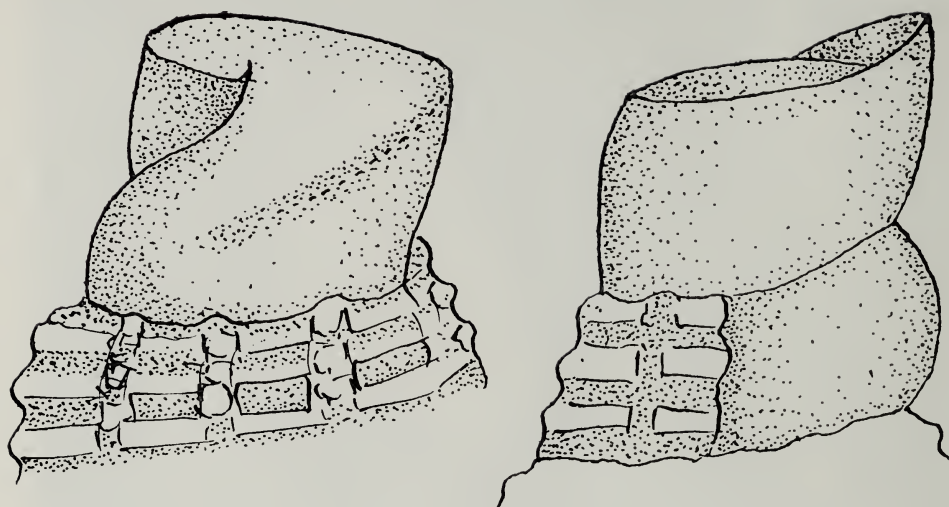
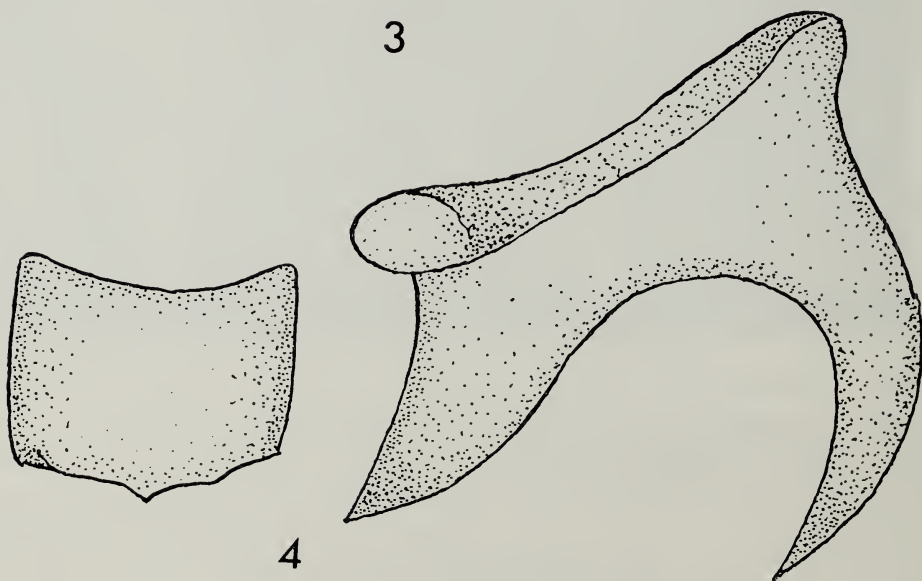


Fig. 1. *Engina farinosa* (Gould). Luatunau'u, W. Samoa; 13.5mm x 6.5mm.

Fig. 2. *Ceratoxancus teramachii* Kuroda. Molokai Channel, Hawaiian Is., 185-205 fathoms; 34.7mm x 16.0mm.



3



4

Fig. 3. *Engina farinosa* (Gould). Protoconch — two views.

Fig. 4. *Engina farinosa* (Gould). Half-row of radula.

1952 *Ceratoxancus teramachii* Kuroda, Publ.Seto. Mar.Lab. 2(2):70, figs. 1, 2 (shell), 3 (operculum), 4 (radula); 1958 Sakurai, Jap.J. Malac. 19:162, figs. 3, 4.

The genus *Ceratoxancus* was proposed by Kuroda (1952) for a mitriform turbinellid species from deep water (c.200 fathoms), off Kii Peninsula. The appended illustration showed the species to have an elongate operculum and turbinellid radula.

A specimen of *C.teramachii* collected in pink coral at Molokai Channel, Hawaiian Islands, 185-205 fathoms, by Mr and Mrs D. Corn (per favour of Dr H. A. Rehder, Smithsonian Institution), has been examined and found to be conspecific with the Japanese *C.teramachii*. The original illustration given by Kuroda (*op.cit.*) has not been well reproduced and a better illustration has been supplied by Sakurai (1958) who illustrated a specimen from off Tosa, Japan. The Hawaiian specimen is moderately broad, and sculptured with unequal and slightly slanting axial riblets which are usually weak or absent on the body whorl and irregular, low, close-set spiral cords which become more pronounced on the siphonal fascicle; the sutures are narrowly sub-canalicate and there is an indication of a slightly deeper presutural groove. The outer lip is constricted at the anterior third and at this point carries a small spur on the edge; this spur is absent in the Hawaiian specimen due to damage to the outer lip at this point. The columellar folds are very strong, typically turbinellid and placed horizontal to the shell's axis. The colour is off-white and the edge of the slight columellar glaze is stained with orange-brown, but Japanese specimens sometimes have a pale brown zone on the body whorl. The species is apparently prone to damage according to the number of repair-scars present on the shell.

The Hawaiian specimen of *C.teramachii* has been found at a depth of about 200 fathoms, which is the same depth as reported by Kuroda (*op.cit.*) for Japanese specimens. The species most probably has a wider Pacific distribution than is known at present.

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